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ANTIMICROBIAL ACTIVITY AND CHEMICAL COMPOSITION OF THE ESSENTIAL OILS OF SIX IRANIAN *Salvia* SPECIES

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The plant world represents an enormous reservoir of biologically active molecules. Essential oils, the odorous principles of plants, are widely employed because of their commercial uses and medicinal properties. Extensive application of essential oils for their antimicrobial activity in food preservations, pharmaceuticals, alternative medicine, and natural therapies has resulted in a large number of studies concerning this effect of essential oils.

Salvia L., with a cosmopolitan distribution and about 900 species, is the largest genus of Lamiaceae family and is a rich source of volatile constituents and biologically active molecules. In Iran, this genus is represented by 58 species of which 17 are endemic [1]. The antimicrobial activity of the essential oils of *Salvia* species is the subject of more than 70 articles, according to the ISI Web of Knowledge[SM]. In this work, the essential oils of six Iranian *Salvia* species, including *S. eremophila*, *S. santolinifolia*, *S. reuterana*, *S. virgata*, *S. multicaulis,* and *S. hydrangea,* are tested for antimicrobial activity. Among these species, only the *S. santolinifolia* and *S. hydrangea* essential oils were the subjects of a previous work [2]. Also the compositions of the oil of these six species have been studied.

Data on the constituents of the six *Salvia* oils are shown in Table 1. According to this table, the first major compounds of *S. eremophila* and *S. santolinifolia* were α-pinene. The major constituents of *S. eremophila* were α-pinene (21.5%), borneol (20.8%), and geranyl linalool (10.7%). In a previous work, α-pinene was also the first major compound of this species with 24.3% of the total oil, and bornyl acetate (18.9%) and camphene (16.0%) were the second and third compounds [8]. In *S. santolinifolia* oil, α-pinene (35.7%), camphor (15.9%), and α-eudesmol (4.9%) were the major compounds. In two previous works, α-pinene was also the first major compound with more than 50% of the total oils in both reports [2–4]. β-Pinene and limonene were the second and third major compounds in both previous works. Hedge, in Flora Iranica, have placed *Salvia* species in several groups and subgroups according to the morphological characters [5]. *Salvia eremophila* and *S. santolinifolia,* which are dwarf desert subshrubs, have been placed together in the subgroup IIa. Relatively similar essential oil compositions of these species are in agreement with their morphological similarities. Caryophyllene oxide (61.5%), β-caryophyllene (8.3%), and borneol (5.6%) were the major compounds of *S. hydrangea*. The essential oils of this species were the subjects of several previous articles, and in all reports, compounds with the caryophyllene skeleton were the major constituents [2, 6–8]. The constituents with this skeleton were also the major compounds in *S. virgata* oil in our work and two previous works [9, 10]. Caryophyllene oxide (26.0%), tetradecanoic acid (11.2%), and hexadecanoic acid (10.5%) were the major compounds in the oil of our work. It seems that caryophyllene backbone compounds are a dominant group in the oil of these two species. Borneol (11.6%), β-caryophyllene (8.5%), and α-pinene (8.3%) were the major compounds of *S. multicaulis*. Previous reports on the oil composition of this species completely differed from each other and also from ours [11–14]. The different localities of the collected plant materials may explain the considerable different chemical compositions of these oils. Benzyl benzoate comprised 75.9% of *S. reuterana* total oil, which was completely different from previous work. *E*-β-Ocimene (32.3%), α-gurjunene (14.1%), and germacrene D (11.2%) were the main components of the oil of previous work [15].

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TABLE 1. The Chemical Constituents of Six *Salvia* Essential Oils, %

Compound	RI	1	2	3	4	5	6	Compound	RI	1	2	3	4	5	6
2-(*E*)-Hexenal	851	-	Tr.	Tr.	0.1	-	0.3	*endo*-Fenchyl acetate	1220	0.1	-	-	-	-	-
3-(*E*)-Hexenol	854	-	-	Tr.	-	-	-	Isobornyl formate	1238		0.1	-	-	0.3	-
Tricyclene	927	0.1	0.5	Tr.	Tr.	1.2	-	Cuminaldehyde	1242	0.1	-	-	-	-	-
α-Thujene	931	Tr.	-	-	-	-	0.3	Carvone	1243	0.1	-	-	-	0.2	-
α-Pinene	937	35.7	21.5	Tr.	1.2	8.3	0.3	Carvacrol methyl ether	1245	-	-	-	-	-	Tr.
Camphene	952	2.1	11.9	Tr.	0.1	7.8	-	Piperitone	1253	-	-	-	-	0.1	-
Benzaldehyde	960	-	-	0.2	-	-	-	*trans*-Sabinene hydrate acetate	1256	0.3	-	-	-	-	-
Sabinene	973	-	-	-	-	-	0.9	Linalyl acetate	1257	-	-	Tr.	-	-	0.2
β-Pinene	979	1.4	0.4	-	0.2	3.5	-	*cis*-Chrysanthenyl acetate	1263	-	-	0.2	-	-	-
1-Octen-3-ol	981	Tr.	0.2	-	-	-	0.2	Geranial	1270	-	-	-	-	-	Tr.
3-Octanone	985	0.2	Tr.	-	-	-	-	(*E*)-Cinnamaldehyde	1272	-	-	Tr.	-	-	-
6-Methyl-5-hepten-2-one	987	-	-	Tr.	-	-	0.1	Isobornyl acetate	1285	-	-	-	0.2	7.3	0.2
Dehydro-1,8-cineol	990	-	-	0.1	-	-	-	Bornyl acetate	1289	2.3	5.4	-	-	-	-
2-Pentyl furan	991	-	-	-	-	-	0.2	Thymol	1291	-	0.1	-	-	-	-
Myrcene	991	0.3	0.8	-	-	1.4	-	Tridecane	1300	-	-	-	-	-	Tr.
α-Phellandrene	1003	0.1	0.1	-	-	0.1	-	Terpinen-4-ol acetate	1300	-	-	-	-	0.1	-
δ-3-Carene	1012	-	0.1	-	-	-	-	Carvacrol	1302	3.4	0.2	-	-	0.2	-
α-Terpipene	1018	0.2	0.4	Tr.	Tr.	0.3	0.2	Myrtenyl acetate	1328	-	Tr.	-	-	-	0.7
p-Cymene	1024	1.3	1.6	Tr.	0.1	4.4	0.4	Bicycloelemene	1338	0.1	-	-	-	Tr.	-
o-Cymene	1028	1.1	-	-	-	-	-	δ-Elemene	1338	-	Tr.	-	0.2	-	-
Limonene	1029	3.0	5.7	Tr.	Tr.	-	0.2	α-Terpinyl acetate	1351	0.3	-	-	-	-	-
1,8-Cineol	1033	0.1	-	-	0.5	6.9	-	Eugenol	1362	-	0.1	Tr.	0.1	-	-
Benzyl alcohol	1036	-	-	Tr.	-	-	-	Meryl acetate	1364	-	-	-	-	0.1	-
(*Z*)-β-Ocimene	1036	0.1	-	-	Tr.	-	-	α-Ylangene	1375	0.3	-	-	-	0.1	-
Benzeneacetaldehyde	1044	-	-	-	-	-	0.1	α-Copaene	1378	0.7	Tr.	-	Tr.	-	0.1
(*E*)-β-Ocimene	1048	0.1	-	-	0.1	-	-	Geranyl acetate	1384	-	-	-	-	0.1	-
γ-Terpinene	1059	0.3	0.2	Tr.	Tr.	0.5	0.4	β-Bourbonene	1385	-	-	-	0.3	-	Tr.
cis-Sabinene hydrate	1070	Tr.	-	-	Tr.	0.5	0.1	(*E*)-β-Damascenone	1386	0.2	-	Tr.	-	-	0.3
trans-Linalool oxide	1072	-	-	Tr.	-	-	-	Tetradecene	1392	-	-	-	-	-	0.2
Benzyl formate	1078	-	-	Tr.	-	-	-	*cis*-Jasmone	1395	-	0.1	-	0.1	-	-
Terpinolene	1090	0.1	0.3	Tr.	Tr.	0.3	0.2	Tetradecane	1400	-	-	-	-	-	0.2
p-Cymenene	1093	0.2	Tr.	Tr.	Tr.	-	-	(*Z*)-Caryophyllene	1407	-	0.1	-	-	-	-
trans-Sabinene hydrate	1100	-	-	-	-	1.2	-	Methyl eugenol	1408	-	-	-	-	0.1	-
Linalool	1101	0.5	0.8	0.1	0.3	-	0.4	α-Gurjunene	1412	0.2	-	-	-	-	-
Nonanal	1104	-	-	-	-	-	0.5	β-Caryophyllene	1420	0.3	8.5	0.2	8.3	8.5	9.1
1-Octen-3-yl acetate	1112	0.1	-	-	-	-	-	β-Ylangene	1423	-	0.1	-	-	-	-
cis-*p*-Menth-2-en-1-ol	1124	-	-	-	Tr.	Tr.	-	β-Copaene	1429	-	-	-	0.2	-	-
β-Fenchol	1124	-	0.1	-	-	-	-	β-Gurjunene	1434	0.1	-	-	-	-	-
α-Campholenal	1126	0.2	0.1	-	-	-	-	*trans*-α-Bergamotene	1435	-	-	-	0.2	-	-
1-Terpineol	1135	0.1	-	-	-	-	-	2-Methylbutyl benzoate	1436	-	-	0.1	-	-	-
trans-Pinocarveol	1141	-	0.1	-	-	-	-	Aromadendrene	1439	1.3	-	-	0.2	0.4	0.3
Camphor	1148	15.9	0.1	-	2.2	13.8	-	α-Humulene	1455	0.1	0.8	Tr.	0.4	0.8	0.7
Comphene hydrate	1151	-	0.2	-	-	-	-	(*E*)-β-Farnesene	1457	-	-	-	2.0	0.4	-
(2*E*,6*Z*)-Nonadienal	1154	-	-	-	-	-	0.2	Geranyl acetone	1458	0.2	-	Tr.	-	-	0.7
Karahanaenone	1160	0.1	-	-	-	-	-	Alloaromadendrene	1461	0.1	-	-	-	-	-
2-(*E*)-Nonenal	1161	-	-	-	-	-	0.2	*trans*-Cadina-1(6),4-diene	1475	-	-	-	0.1	-	-
Pinocarvone	1168	0.3	0.1	-	-	0.2	-	γ-Muurolene	1480	0.7	Tr.	-	0.1	0.1	-
Borneol	1171	2.0	20.8	-	5.6	11.6	-	*ar*-Curcumene	1483	-	-	-	-	-	Tr.
Terpinen-4-ol	1180	0.9	2.3	Tr.	0.5	2.0	0.4	γ-Himachalene	1484	-	-	-	0.1	-	-
p-Cymen-8-ol	1185	-	0.2	-	-	-	-	Germacrene-D	1484	0.1	-	-	-	-	0.1
p-Methyl acetophenone	1185	-	-	Tr.	-	-	-	β-Selinene	1487	-	Tr.	-	-	0.2	-
α-Terpineol	1190	1.1	0.8	0.2	2.5	0.5	0.1	(*E*)-β-Ionone	1487	-	-	-	-	-	0.5
Myrtenol	1196	0.2	-	-	-	0.2	-	*cis*-β-Guaiene	1493	0.1	-	-	-	-	-
Myrtenal	1198	-	-	-	-	0.1	-	Valencene	1496	1.3	-	-	-	-	-
Estragole	1199	-	1.2	-	-	-	-	Bicyclogermacrene	1497	-	-	-	0.3	0.4	-
Dodecane	1200	-	-	-	-	-	Tr.	α-Selinene	1497	-	Tr.	-	-	-	-
Decanal	1203	-	-	-	-	-	0.1	Pentadecane	1500	-	-	-	-	-	0.2
Verbenone	1207	0.1	-	-	-	-	-	α-Muurolene	1501	-	-	-	-	0.2	-
β-Cyclocitral	1218	-	-	-	-	-	Tr.	Aromadendra-1(10),4(15)-diene	1505	-	-	-	0.1	-	-

TABLE 1. (continued)

Compound	RI	1	2	3	4	5	6	Compound	RI	1	2	3	4	5	6
Cuparene	1505	-	-	-	-	-	0.1	(2*Z*,6*Z*)-Farnesol	1719	-	-	-	-	-	0.3
(*E,E*)-α-Farnesene	1508	-	-	0.2	-	Tr.	Tr.	Cyclocolorenone	1762	0.1	-				
β-Bisabolene	1508	-	-	-	0.5	-	-	Benzyl benzoate	1763	-	-	79.9	-	-	1.0
γ-Cadinene	1512	0.6	-	-	-	0.8	-	Tetradecanoic acid	1780	-	-	-	-	-	11.2
δ-Cadinene	1526	2.0	Tr.	-	-	0.9	Tr.	14-Oxocalamenene	1785	0.1	-	-	-	-	-
trans-Cadina-1(2),4-diene	1533	0.2	-	-	-	-	-	6,10,14-Trimethyl-2-	1846	0.1	Tr.	0.1	0.1	0.1	3.7
α-Cadinene	1538	0.1	-	-	-	0.1	-	pentadecanone							
α-Calacorene	1545	0.3	-	-	-	0.1	-	Benzyl salicylate	1869	-	-	0.1	-	-	-
β-Caryophyllene oxide	1551	-	-	-	-	-	0.5	Nonadecane	1900	Tr.	-	-	-	-	-
β-Calacorene	1566	-	-	-	-	Tr.	-	Isopimara-9(11),15-diene	1907	-	Tr.	-	-	-	-
Caryolan-8-ol	1572	-	0.1	-	-	-	-	Farnesyl acetone	1917	0.2	Tr.	-	0.1	-	0.8
Spathulenol	1581	1.4	-	-	0.2	-	-	Methyl hexadecanoate	1925	-	-	-	-	-	0.2
Caryophyllene oxide	1583	-	0.2	0.5	61.5	6.2	26.0	(*E*)-2,6-Dimethyl-10(*p*-tolyl)-	1956	-	-	4.9	-	-	-
Clovenol	1591	-	0.1	-	-	-	-	undeca-2,6-diene							
Salvial-4(14)-en-1-one	1595	-	-	-	0.6	-	-	Hexadecanoic acid	1978	-	-	-	0.1	-	10.5
Viridiflorol	1595	0.8	-	Tr.	-	0.2	-	Manoyl oxide	1998	-	-	0.3	-	-	-
Hexadecane	1600	-	-	-	-	-	0.5	13-*epi*-Manoyl oxide	2017	-	-	0.2	-	-	-
Geranyl 2-methylbutanoate	1603	-	-	Tr.	-	-	-	Geranyl linalool	2028	0.7	10.7	0.1	-	-	-
Humulene epoxide II	1610	-	Tr.	-	0.5	0.8	1.4	Abietatriene	2055	-	0.1	-	-	-	0.8
1,10-di-epicubenol	1620	-	-	-	-	0.1	-	Manool	2060	-	-	0.4	-	-	-
5-Guaien-11-ol	1625	-	-	-	0.2	-	-	Labda-7,14-dien-13-ol	2093	-	-	-	-	-	0.6
γ-Eudesmol	1632	0.3	-	-	-	-	-	Heneicosane	2100	-	-	-	-	-	0.3
Caryophylla-4(14),	1643	-	0.3	-	1.7	2.2	1.5	Phytol	2128	-	-	-	-	-	4.1
8(15)-dien-5-β-ol								Ethyl linoleolate	2161	-	-	-	0.1	-	4.1
β-Eudesmol	1653	-	-	-	3.5	0.7	0.4	Octadecanoic acid	2181	-	-	-	-	-	0.4
α-Cadinol	1656	-	-	-	-	0.5	-	Docosane	2200	-	-	-	-	0.1	-
α-Eudesmol	1657	4.9	-	-	-	-	-	Sclareol	2226	-	-	10.5	-	-	0.5
14-Hydroxy-9-epi-	1672	-	-	-	-	0.8	1.5	Tricosane	2300	-	-	-	0.1	-	0.3
(*E*)-caryophyllene								*trans*-Ferruginol	2332	-	0.1	-	-	-	-
Cadalene	1680	0.2	-	-	-	0.2	-	Tetracosane	2400	-	-	0.1	-	-	-
α-Bisabolol	1688	-	-	-	0.4	-	-	Pentacosane	2500	-	0.5	-	0.1	-	-
cis-14-*nor*-Muurol-5-en-4-one	1692	0.2	-	-	-	-	-	Total		93.6	97.5	83.8	95.7	98.5	91.1
6α-Hydroxygermacra-1(10),	1700	1.1	-	-	-	0.3	-	Number of ident. compounds		72	57	44	53	58	66
4-diene								Yield, %		0.5	0.2	0.06	0.09	0.3	0.02
Heptadecane	1700	-	-	-	-	-	1.1	$[\alpha]_D^{25}$ +, deg.		7.5	6.5	8.5	10.1	18	6

Tr.: trace (<0.05%), RI: retention indices relative to C_8-C_{28} *n*-alkanes on HP5. The components are listed in order of elution from the HP-5 column.

Color of oil: yellow.

Data on localities, dates, and Herbarium numbers:

1 - *S. eremophila* (Khorsooyeh, Darab, Fars; 27.03.04; 23500);

2 - *S. santolinifolia* (Fork toward Rostagh, Darab, Fars; 30.03.04; 23658);

3 - *S. reuterana* (Dena mountain, Padena, Kohgilooyeh; 20.06.05; PC14-5-76);

4 - *S. virgata* (Sisakht, Kohgilooyeh; 20.06.05; PC14-9-80);

5 - *S. multicaulis* (Dasht-e Arjan, Fars; 29.05.04; PC83-5);

6 - *S. hydrangea* (Derak mountain, Shiraz, Fars; 06.05.05; PC6-7-28).

TABLE 2. Antimicrobial Activities of the Essential Oils of Six *Salvia* Species

Microorganism	Zone of inhibition in mm mean (SD)						Antibiotics (2 μg/disc)		
	1	2	3	4	5	6	Ketoconazole	Gentamycin	Ampicillin
K. pneumonia PTCC (1053)	14.6 (0.19)	14.0 (0)	12.3 (0.19)	13.3 (0.19)	11.0 (0.19)	8.3 (0.38)	-	13.0 (0)	-
S. aureus PTCC (1112)	14.0 (0)	6.0 (0)	12.3 (0.57)	13.0 (1)	13.3 (1.5)	11.0 (0)	-	-	15.0 (0)
S. epidermidis PTCC (1114)	12.6 (0.57)	7.0 (0)	13.3 (0.57)	15.3 (0.57)	15.6 (2.4)	15.3 (0.57)	-	15.0 (0)	-
E.coli PTCC (1330)	9.3 (0.57)	14.3 (0.5)	14.5 (1.1)	10.3 (0.57)	12.6 (0.57)	15.3 (0.57)	-	15.0 (0)	-
S. typhi PTCC (1639)	6.0 (0)	16.0 (0)	14.0 (0.57)	13.3 (0.25)	12 (0)	14.3 (0.5)	-	14.0 (0)	-
B. subtilis PTCC (1023)	7.6 (0.19)	8 (0)	6.0 (0)	6.0 (0)	6.6 (0.5)	7.3 (0.5)	-	-	15 (0)
A. niger PTCC (5010)	6.0 (0)	10.0 (0)	7.0 (0)	7.0 (0)	6.0 (0)	6.0 (0)	-	-	-
C. albicans PTCC (5027)	6.0 (0)	7.0 (0)	6.0 (0)	7.3 (0.19)	6.0 (0)	6.3 (0.19)	-	-	-

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1 - *S. eremophila*; 2 - *S. santolinifolia*; 3 - *S. reuterana*; 4 - *S. virgata*; 5 - *S. multicaulis*; 6 - *S. hydrangea*.

Antimicrobial assay results are presented in Table 2. As can be seen, all the oils show considerable effect against all the microorganisms. The greatest effect of *S. santolinifolia* was against gram negative bacteria; in two cases, *K. pneumonia* and *S. typhi*, its effect was better than gentamycin. It was also very effective against two tested yeasts. *S. eremophila* oil was also very effective against *K. pneumonia*. It had a good effect against *S. aureus*. The best effect of *S. multicaulis*, *S. hydrangea,* and *S. virgata* was against *S. epidermidis*. In light of the fact that caryophyllene-skeleton compounds constituted the majority of *S. virgata* and *S. hydrangea* oil compositions and β-caryophyllene is one of the major compounds of *S. multicaulis* oil, this effect can be attributed to these structures. *S. virgata's* effect against *C. albicans* was also considerable and *S. hydrangea* oil was also effective against *S. typhi* and *E. coli*. *S. reuterana* oil was most effective against *S. typhi* and *E. coli* which can be related to benzyl benzoate, which comprises more than three-fourths of the total oil of this species. None of the six examined species was active against *Bacillus subtilis*.

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